

## UNIVERSITI MALAYSIA PAHANG

### DECLARATION OF THESIS AND COPYRIGHT

Author's full name : RAJA SARAVANA KUMAR A/L SELVAKUMAR  
Date of birth : 17<sup>TH</sup> NOVEMBER 1985  
Title : DESIGN OF MULTIPLE MICROCONTROLLERS  
PLATFORM FOR USE IN ACADEMIC  
ENVIRONMENT  
Academic Session : 2011 / 2012

I declare that this thesis is classified as:

☐

**CONFIDENTIAL**

(Contains confidential information under the Official Secret Act 1972)\*

☐

**RESTRICTED**

(Contains restricted information as specified by the organization where research was done)\*

☒

**OPEN ACCESS**

I agree that my thesis to be published as online open access (Full text)

I acknowledge that Universiti Malaysia Pahang reserve the right as follows:

1. The Thesis is the Property of Universiti Malaysia Pahang.
2. The Library of Universiti Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make the copies of the thesis for academic exchange.

Certified By:

\_\_\_\_\_  
(Signature of Student)

\_\_\_\_\_  
(Signature of Supervisor)

851117-10-5945

DR. KAMARUL HAWARI GHAZALI

New IC / Passport Number  
Date : 9<sup>TH</sup> JULY 2012

Name of Supervisor  
Date: 9<sup>TH</sup> JULY 2012

**NOTES** : \*If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reason for confidentiality or restriction.

DESIGN OF MULTIPLE MICROCONTROLLERS PLATFORM FOR USE IN  
ACADEMIC ENVIRONMENT

RAJA SARAVANA KUMAR A/L SELVAKUMAR

Thesis submitted in fulfilment of the requirements  
For the award of the degree of  
Master of Engineering in Electronics

Faculty of Electrical & Electronics Engineering  
UNIVERSITI MALAYSIA PAHANG

JULY 2012

## **SUPERVISOR'S DECLARATION**

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering in Electronics.

Signature : \_\_\_\_\_  
Name of Supervisor : DR. KAMARUL HAWARI BIN GHAZALI  
Position : SENIOR LECTURER,  
FACULTY OF ELECTRICAL &  
ELECTRONICS ENGINEERING,  
UNIVERSITI MALAYSIA PAHANG  
Date : 9<sup>TH</sup> JULY 2012

Signature : \_\_\_\_\_  
Name of Supervisor : MR. NIK MOHD KAMIL BIN NIK YUSOFF  
Position : SENIOR LECTURER,  
FACULTY OF ELECTRICAL &  
ELECTRONICS ENGINEERING,  
UNIVERSITI MALAYSIA PAHANG  
Date : 9<sup>TH</sup> JULY 2012

## STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature	:	_____
Name of Student	:	RAJA SARAVANA KUMAR A/L SELVAKUMAR
ID Number	:	MEL 09002
Date	:	9 <sup>TH</sup> JULY 2012

## TABLE OF CONTENTS

	<b>Page</b>
<b>TITLE PAGE</b>	I
<b>SUPERVISOR’S DECLARATION</b>	II
<b>STUDENT’S DECLARATION</b>	III
<b>DEDICATION</b>	IV
<b>ACKNOWLEDGEMENTS</b>	V
<b>ABSTRACT</b>	VI
<b>ABSTRAK</b>	VII
<b>TABLE OF CONTENTS</b>	VIII
<b>LIST OF TABLES</b>	XII
<b>LIST OF FIGURES</b>	XIII
<b>LIST OF SYMBOLS</b>	XVII
<b>LIST OF ABBREVIATIONS</b>	XVIII

### **CHAPTER 1      INTRODUCTION**

1.1	Background of the Research	1
1.2	Research Problem Description	3
1.3	Research Objective	3
1.4	Scope of the Project	4
1.5	Research Methodology	5
1.6	Project Contributions	7
1.7	Thesis Organization	8

### **CHAPTER 2      LITERATURE REVIEW**

2.1	Introduction	9
-----	--------------	---

2.2	Criteria of Choosing a Microcontroller	13
2.2.1	Determine the Performances of Microcontroller	13
2.2.2	Mapping I/O to Peripherals in Microcontroller	16
2.2.3	Mode of Operation in Microcontroller	18
2.2.4	The Selection Process of a Microcontroller	19
2.3	Microcontroller Concept	21
2.4	Implementation of Development Tool	23
2.4.1	V-Diagram of Development Tool Design Flow	24
2.5	Surveys	25
2.6	Related Work	29
2.7	Summary	34

## **CHAPTER 3      HARDWARE DESIGN**

3.1	Introduction	36
3.2	System Board of MicroEVAT	37
3.2.1	Reset Circuit Module	38
3.2.2	Serial Communication Module	39
3.2.3	Mode Selector Module	42
3.3	Memory Board of MicroEVAT	43
3.3.1	Address Decoder Module	44
3.3.2	External Memory Module	47
3.4	Application Board of MicroEVAT	48
3.4.1	Seven Segment Display Module	49
3.4.2	16-Segment Display Module	51
3.4.3	Dot Matrix Display Module	52
3.4.4	Application Examples	53
3.4.5	Keypad Module	54
3.4.6	Stepper Motor Module	55
3.4.7	LCD Module	56
3.4.8	Graphic LCD Module	58
3.4.9	Temperature Sensor Module	60
3.5	Memory Map of MicroEVAT	60
3.6	Summary	63

## **CHAPTER 4      SOFTWARE DESIGN**

4.1	Introduction	64
4.2	Software Tools	65
	4.2.1    X-CTU	65
4.3	Program Code for MicroEVAT Module	68
	4.3.1    Serial Interface	70
	4.3.2    Memory Interface	75
4.4	IDE Interface – RATNA Terminal	82
	4.4.1    Main Screen	84
	4.4.2    Microcontroller Selection Subroutine	85
	4.4.3    Tiny PIC Bootloader	88
4.5	Summary	89

## **CHAPTER 5      RESULTS AND TESTING**

5.1	Introduction	90
5.2	System Board Testing	91
5.3	MicroEVAT – Preliminary Testing	94
	5.3.1    Power Supply Testing	94
	5.3.2    Serial Communication Interfaces Test	98
5.4	MicroEVAT – Subsequent Testing	99
	5.4.1    Application Module Test	99
	5.4.2    IDE Interfaces Test	101
5.5	Summary	102

## **CHAPTER 6      CONCLUSION**

6.1	Concluding Remarks	103
6.2	Achievements	105
6.3	Recommendations of Future Work	106

<b>REFERENCES</b>	107
-------------------	-----

<b>APPENDICES</b>	118
A        Schematics Diagram of MicroEVAT	118
B        Screen Shots of RATNA Terminal	146
C        MicroEVAT's Application Module Testing	150
D        Survey	153
E        Hexadecimal Table for Application Module	158
F        Address Allocation for Application Module	164
G        List of Publications	168



## LIST OF TABLES

<b>Table No.</b>	<b>Title</b>	<b>Page</b>
2.1	Comparison of MicroEVAT with Conventional system	12
2.2	Summary of previous work	32
3.1	Mode Selector for Freescale HC11	43
3.2	Mode Selector for MCS51	43
3.3	Logic between PSEN* and RD* for MCS51 microcontroller	48
3.4	Memory Map of MicroEVAT system (MC68HC11E1)	61
3.5	Memory Map of MicroEVAT system (P89C51RD2)	62
3.6	Memory Map of MicroEVAT system (PIC18F452)	63
4.1	Source and Destination Address of MicroEVAT's XBEE modems	67
4.2	Baud Rate Divide Value for Freescale HC11	71
4.3	The relation between SCON register and Serial Mode Function	72
4.4	The function of each subroutine for Freescale HC11 and MCS51 microcontroller	87
4.5	The function of subroutine for Tiny PIC Bootloader	88
5.1	The testing results for current and thermal load for MicroEVAT system	96

## LIST OF FIGURES

<b>Figure No.</b>	<b>Title</b>	<b>Page</b>
1.1	The research project implementation flow chart	6
2.1	Guideline of choosing the suitable microcontroller	14
2.2	Complex technologies characterizing methodology	22
2.3	Microcontroller conceptual map	23
2.4	V-diagram of development tool design flow	24
2.5	Pie chart on number of students by faculty program	26
2.6	Bar graph on number of student with type of microcontroller	26
2.7	Bar graph on number of students with type of programming language	27
2.8	Bar graph on elements of microcontroller studies with number of students	28
3.1	The Proposed Flow Diagram of the MicroEVAT system	37
3.2	The block diagram of the MicroEVAT system board	38
3.3	The schematic diagram of reset circuit modules for MicroEVAT system	38
3.4	The schematics diagram of Serial Communication module using DS275	40
3.5	The schematics diagram of USB module using FT232RL	41
3.6	The schematics diagram of ZigBEE module using XBEE PRO 4214A	42

3.7	The schematic diagram of mode selector module	43
3.8	The block diagram of the MicroEVAT memory board	44
3.9	The schematic diagram of addressing module using SN74LS138 3-to-8 address decoder	45
3.10	The Address / Data De-multiplexing module for Freescale HC11 microcontroller	46
3.11	The Address / Data De-multiplexing module for MCS51 microcontroller	46
3.12	The schematics diagram of external memory interface using AT28C64B as EEPROM and HY6264 as RAM	47
3.13	The block diagram of MicroEVAT application board	49
3.14	The schematics diagram of Seven - Segment display in expandable interface	50
3.15	The schematics diagram of Seven - Segment display in non-expandable interface	50
3.16	The schematics diagram of 16 - Segment display in expandable interface	51
3.17	The schematics diagram of Dot Matrix in expandable interface	52
3.18	Dot Matrix represents character 'B'	53
3.19	The schematics diagram of 'Traffic Light' in expandable interface	53
3.20	The schematics diagram of Keypad in expandable interface	54
3.21	The schematics diagram of Keypad in non-expandable interface	55
3.22	The schematics diagram of Stepper Motor in expandable interface	55
3.23	The schematics diagram of Stepper Motor in non-expandable interface	56
3.24	The schematics diagram of LCD in expandable interface	57

3.25	The schematics diagram of LCD using Microchip PIC	58
3.26	Memory map of GLCD 128 X 64	58
3.27	The schematics diagram of GLCD using Microchip PIC	59
3.28	The schematics of LM35 Temperature Sensor using Freescale HC11	60
4.1	The screen shot of X-CTU software with XBEE PRO 4214A modem communication test	65
4.2	The MicroEVAT prototype system with XBEE PRO 4214A modems	66
4.3	The screen shot of Modem Configuration	67
4.4	The flow chart of the source code implementation	69
4.5	The flow chart of SCI Initialization in Freescale HC11	71
4.6	The flow chart of Serial Communication Initialization in MCS51 microcontroller	73
4.7	The flow chart of Asynchronous Serial Transmission and Reception Initialization in Microchip PIC microcontroller	74
4.8	The example of SREC file formats	76
4.9	The flow chart of uploading program subroutine for Freescale HC11	77
4.10	The flow chart of executing subroutine program for Freescale HC11	78
4.11	The example of I8HEX file formats	80
4.12	The flow chart of uploading program subroutine for both MCS51 and Microchip PIC microcontroller	81
4.13	The screen shot of RATNA Terminal main screen	83
4.14	The subroutine program of MSComm	84

4.15	The screen shot of RATNA Terminal for Freescale HC11	85
4.16	The screen shot of RATNA Terminal for MCS51	86
4.17	The screen shot of RATNA Terminal using Tiny PIC Bootloader for Microchip PIC	86
5.1	The experimental setup for MicroEVAT prototype system	91
5.2	The schematics diagram of Bar Graph free running test in expended mode	91
5.3	The schematics diagram of Bar Graph free running test in bootstrap mode	92
5.4	The program testing for Freescale HC11 microcontroller	92
5.5	The program testing for MCS51 microcontroller	93
5.6	The program testing for Microchip PIC microcontroller	93
5.7	The schematics diagram of current load measuring for System board power supply module	94
5.8	The schematics diagram of current load measuring for Application board power supply module	95
5.9	The current load measurements	95
5.10	The thermal load measurements	95
5.11	Line graph on Load current with Junction Temperature of Voltage regulator at constant output voltage of 5VDC	97
5.12	The flow chart of serial communication interface for MicroEVAT system	98
5.13	The example of testing result for some application module	99
5.14	The flow chart of application board testing	100
5.15	The flowchart of graphical-oriented testing	101
5.16	Plan View of the MicroEVAT prototype system	102

## LIST OF SYMBOLS

$R_X$	Resistor
$C_X$	Capacitor
$S_X$	Switch
$SW_X$	Push Button, Selector Switch
$D_X$	Diode
$J_X$	Connector Jack
$Y_X$	Crystal
$U_X$	Integrated Circuit, Chip
$P_X$	Data Connector
$Q_X$	Transistor
$JP_X$	Jumper Connector
$MG_X$	Motor
$a$	Angle per step
$s$	Number of steps per rotation
$\theta$	Prescaler Phase
$F_{osc}$	Oscillator Frequency, Crystal Value
$\beta$	Desired Baud rate
$C$	Clock Mode

## LIST OF ABBREVIATIONS

MicroEVAT	Multi-microcontroller Evaluation Tool
CPU	Central Processing Unit
CCU	Central Controlling Unit
MCS	Microcontroller systems
I/O	Input and Output
ALU	Arithmetic Logic Unit
LCD	Liquid Crystal Display
GLCD	Graphic LCD
DC	Direct Current
DIP	Dual-In-Line Package
ROM	Read Only Memory
RAM	Random Access Memory
IR	Instruction Register
SP	Stack Pointer
EEPROM	Electrically Erasable Programmable Read Only Memory
RxD	Receiving Signal
TxD	Transmitting Signal
GND	Ground

BCD	Binary Coded Decimal
DA	Data Available
CE	Chip Enable
ADC	Analog to Digital Converter
EPROM	Erasable Programmable Read Only Memory
ASCII	American Standard Code for Information Interchange
CR	Carriage Return
LF	Linefeed
GUI	Graphic User Interface
IDE	Integrated Development Environment
VS	Visual Studio
LED	Light Emitted Diode
FMEA	Failure-Mode Effect Analysis
WP11	Windows Programming for HC11
SREC	Motorola S-Record Binary File
I8HEX	Intel 8-bit Binary File
PC	Program Counter
USB	Universal Serial Bus
X-CTU	XBEE Configuration Tool Unit
UART	Universal Asynchronous Receiver Transmitter
USART	Universal Synchronous Asynchronous Receiver Transmitter



## **ABSTRACT**

Embedded systems have an everyday presence and direct impact in every day's lives. Therefore, learning institutions are continuously improving their courses in microcontroller and embedded system programming. Although the diversity of curriculums, the availability of learning tools, where the student can practice and improve their skills, is a key factor to the success of the learning process. The platform developed and presented in this thesis results from author's experience in teaching and learning embedded systems. From the analysis of teaching and learning needs, a learning environment based on the Freescale HC11, MCS51, and Microchip PIC 18 Series families was designed, which led to the Multiple Microcontrollers Evaluation Tool (MicroEVAT). This tool can be expanded by modules and adjusted at a specific time to student's real needs. All modules can be interconnected by an IDE bus, allowing expanding the capabilities of the platform. Series of test-run are conducted to verify MicroEVAT system performance. The developed modules allow the practice of subjects related with digital Input and Output interface, analogue interface, user interface, wireless communications, and energy management and conservation. The hardware, software and system architecture used to develop the MicroEVAT are described in detailed in this thesis. In this respect, the MicroEVAT were applicable for education and expose the electrical engineering students to the understanding of microcontroller in electronic design field and embedded systems. The work done for this research project gives solid bases and chances for fast evolution in embedded control technology research.

## **ABSTRAK**

Sistem kawalan terbenam mempunyai peranan khas dan kesan langsung didalam kehidupan seharian. Oleh itu, institusi pengajian sentiasa memperbaiki kursus-kursus yang berkaitan dengan mikropengawal dan pengaturcaraan sistem terbenam dari masa ke semasa. Dengan kepelbagaian kurikulum dan alat pembelajaran, dimana pelajar boleh berlatih dan meningkatkan kemahiran mereka, merupakan faktor utama kepada kejayaan proses pembelajaran mereka. Platform yang dibangunkan dan dibentangkan di dalam tesis ini adalah hasil daripada pengalaman penulis dalam pengajaran dan pembelajaran sistem kawalan terbenam. Daripada analisis keperluan pengajaran dan pembelajaran, persekitaran pembelajaran yang berdasarkan mikropengawal Freescale HC11, MCS51, dan Mikrochip siri keluarga PIC 18 telah direka (MicroEVAT). Alat ini dapat dikembangkan dengan modul dan diselaraskan pada masa ke semasa mengikut keperluan pelajar. Semua modul boleh disaling dengan bas IDE untuk mempertingkatkan keupayaan platform ini. Beberapa siri ujian telah dijalankan untuk mengesahkan prestasi sistem MicroEVAT. Modul-modul yang dibangunkan, membenarkan dalam penggunaan dalam subjek yang berkaitan dengan digit, analog, komunikasi tanpa wayar, pengurusan dan pemuliharaan tenaga. Seni bina perkakasan, perisian dan sistem yang digunakan untuk membangunkan MicroEVAT telah dinyatakan dengan terperinci didalam tesis ini. Dalam hal ini, MicroEVAT dapat diamalkan melalui pendidikan dan mendedahkan pelajar kejuruteraan elektrik kepada pemahaman mikropengawal dalam bidang reka bentuk elektronik dan sistem terbenam. Kerja yang dilakukan untuk projek penyelidikan ini telah memberikan asas yang kukuh dan peluang untuk evolusi yang cepat didalam penyelidikan teknologi kawalan terbenam.

## REFERENCES

- Abdul Aziz, H., Nik Yusoff, N.M.K. and Sapien, M.Z.B.M. 2010. MINI11: Microcontroller Development Board for SCL Approach. *Proceedings of 2010 IEEE Student Conferences on Research and Development*, pp. 178-182
- Al-Dhaher, A.H.G. 2001. Integrating Hardware and Software for the Development of Microcontroller Based Systems. *Elsevier Journal of Microprocessors and Microsystems*. **25**(7): 317-328
- Alves, G.R. and Martinas Ferreira, J.M. 1999. From Design-for-Test to Design-for-Debug-and-Test: Analysis of Requirements and Limitations for 1149.1. *17<sup>th</sup> IEEE VLSI Test Symposium*, pp. 479-480
- Arefin, A.S., Masum Habib, K.M., Sultana, R. and Lutful Kabir, S.M. 2007. Designing a Low Cost Microcontroller-based Device for Multipurpose Learning. *IEEE Transactions on Education*. **44**(7): 88-94
- Azad, A.K.M. and Lakkaraju, V.K. 2003. Development of a Microcontroller Laboratory Facility for Directing Students towards Application Oriented Projects. *Proceedings for American Society for Engineering Education IUIN sectional conference*, pp. 145-151
- Brawicz, A. and Morawski, R. 1999. Teaching Measuring systems beyond the year 2000. *IEEE Instrumentation Measurement Magazine*. **2**(1): 20-27
- Brockman, J. 1998. Process Multi-Circuit Optimization. *Proceedings for Design Automation Conference*, pp. 382-387

- Cady, F. 1997. *Software and Hardware Engineering – Motorola M68HC11*. London: Oxford University Press
- Cady, F. 2008. M68HC11 Microcontroller Board and Prototyping, MC68HC11 and MC68HC12. <http://www.coe.montana.eduJee/cady/ee361/hc11nks.htm> (23 July 2010)
- Caspi, P., Sangiovanni-Vincentelli, A. and Almeida, L. 2005. Guidelines for a Graduate Curriculum on Embedded Software and Systems. *ACM Transactions on Embedded Computing System*. **4**(3):587-611
- Chandrakasan, A.P., Sheng, S. and Brodersan, R.W. 1992. Low Power CMOS Digital Design. *IEEE Journal of Solid-State Circuit*. **27**: 473-477
- Cheng, B.H.C., Rover, D.T. and Mutka, M.W. 1998. A Multi-pronged Approach to Bringing Embedded System into Undergraduate Education. *ASEE Annual Conferences*, pp. 117-121
- Ching, P.C., Cheng, Y.H. and Ko, M.H. 1994. An In Circuit Emulator for TMS320C25. *IEEE Transactions on Education*. **37**(1): 51-56
- Cho, J.M., Choi, S.I. and Lee, D.K. 2003. A Flash based Multimedia Interactive Tutoring System for Distance Education of Biomedical Engineering Student: New Approach to Teaching Microcontroller based System. *Proceedings of the 25<sup>TH</sup> Annual International Conference of the IEEE EMBS*. pp. 3540-3543
- Chu, R.H., Lu, D.D. and Sathiakumar, S. 2008. Project Based Lab Teaching for Power Electronics and Drives. *IEEE Transactions on Education*. **51**(1): 108-113
- Correa, C.R. and Awad, S.S. 2003. Embedded Controller Software and Algorithm Development Tool. *IEEE Transactions on Instrumentation and Measurement*. **52** (3): 885-890

- Databeans. 2009. Microcontroller Market Share, Electronics.ca Publications, Mar 2010.  
<http://www.electronics.ca/publications/products/2009-Microcontrollers-Market-Share.html> (2 August 2010)
- Dutson, A.J., Todd, R.H., Magleby, S.P. and Sorensen, C.D. 1997. A Review of Literature on Teaching Engineering Design Through Project-oriented Capstone Courses. *Journal on Engineering Education*. **32**: 17-28
- Ferreira, L.F., Matos, E.L., Menendez, L.M. and Mandado, E. 2005. MILES: A microcontroller Learning System combining Hardware and Software Tools. 35<sup>th</sup> ASEE / IEEE Frontiers in Education Conferences, pp. 77-81
- Ferrero Martin, F.J., Campro Rodriquez, J.C. and Alvarez Anton, J.C. 2005. An Electronics Instrumentation Design Project for Computer Engineering Students. *IEEE Transactions on Education*. **48**(3): 472-481
- Flammini, A., Marioli, D. and Taroni, A. 2001. A Low Cost Diagnostic Tool for Stepping Motors. *IEEE Transactions on Instrumentation and Measurement*. **50**(1): 157-162
- Hadzic, D. 2004. *Application Layer - Communication Protocol for Home Automation*. M.Eng. Thesis. University of Oslo, Norway
- Hedley, M. and Barrie, S. 1998. An Undergraduate Microcontroller System Laboratory. *IEEE Transactions on Education*. **41**(4): 345-349
- Hennessy, J.L. and Patterson, D.A. 1996. *Computer Architecture, A Quantitative Approach, Second Edition*. USA: Morgan Kaufmann
- Hilbor, R.B. 1994. Team Learning for Engineering Students. *IEEE Transactions on Education*. **37**(2): 207-211

- Huang, I.J., Kao, C.H., Chen, H.M. and Juan, C.N. 2002. A Retargetable Embedded In-Circuit Emulation Module for Microprocessor. *IEEE Transactions on Design and Test of Computers*. **40**(2): 28-38
- Huber, N., Hromalik-Pouchet, M.S., Carozzi, T.D., Gough, M.P. and Buckley, A.M. 2011. Parallel processing speed increase of the one-bit auto-correlation function in hardware. *Elsevier Journal on Microprocessors and Microsystems*. **35**: 297–307
- Husmann, S. and Jensen, D. 2007. Crazy Car Race Contest: Multicourse Design Curriculum in Embedded System Design. *IEEE Transactions on Education*. **50**(1): 61-67
- Jackson, D.J. and Caspi, P. 2005. Embedded Systems Education: Future Directions, Initiatives, and Cooperation. *SIGBED Review (Special Issue on the First Workshop on Embedded System Education)*. **2**(4): 113-121
- Kaeli, D. and Platcow, R. 2006. Experiences with the Blackfin Architecture in an Embedded System Lab. *Proceedings for 2006 Workshop on Computer Architecture Education*. pp. 301-307
- Kaufman, D.B., Felder, R.M. and Fuller, H. 2000. Accounting for Individual Learning Effort in Cooperative Learning Teams. *Journal on Engineering Education*. **38**: 237-241
- Kavvadias, N., Neofotistos, P., Nikolaidis, S., Kosmatopoulos, K. and Laopoulos, T. 2004. Measurement Analysis of the Software-Related Power Consumption in Microprocessors. *IEEE Transactions on Instrumentation and Measurement*. **53**(4): 1106–1112
- Khan, T.H. and Ninad, N.A. 2006. Design of a Low Cost 8051 Architecture Based Microcontroller Learning Kit. *Asian Journal of Information Technology*. **5**(2): 213-218

- Konstantakos, V., Chatzigeorgiou, A., Nikolaidis, S. and Laopoulos, T. 2008. Energy Consumption Estimation in Embedded Systems. *IEEE Transactions on Instrumentation and Measurement*. **57**(4): 797-804
- Kroupis, N. and Soudris, D. 2011. FILESPPA: Fast Instruction Level Embedded System Power and Performance Analyzer. *Elsevier Journal on Microprocessors and Microsystems*. **35**: 329-342
- Laopoulos, T. 1999. Teaching Instrumentation and Measurement in the Complex Systems Era. *IEEE Instrumentation Measurement Magazines*. **2**(1): 28-30
- Lawrence, P.D. and Mauch, K. 1987. *An Introduction Real-time Microcontroller System Design*. USA: McGraw-Hill
- Lee, C.S., Su, J.H., Lin, K.E. and Chang, J.H. 2010. A Project Based Laboratory for Learning Embedded System Design with Industry Support. *IEEE Transactions on Education*. **50**(2): 173-181
- Lee, C.S., Wang, Y.N., Su, J.H., Chang, C. and Chen, H.S. 2006. Work in Progress: A Joint Effort of Lunghwa University and Holtek Semiconductor Inc. on Improving Microcontroller Education. *36<sup>th</sup> ASEE / IEEE Frontiers in Education Conference*, pp. 128-129
- Ling, L.C. 2008. *The MC68HC11 Development Board with Integrated Development Environment (IDE)*. B.Eng. Thesis. Universiti Malaysia Pahang, Malaysia
- Ma, C., Li, Q., Liu, Z. and Jin, Y. 2010. Low Cost AVR Microcontroller Development Kit for Undergraduate Laboratory and Take-home Pedagogies. *2010 2nd International Conference on Education Technology and Computer*, pp. 35-38
- MacNamee, C. and Heffernan, D. 2000. Emerging On-Chip Debugging Techniques for Real-Time Embedded Systems. *IEEE Journal Computing and Control Engineering*. **11**(6): 295-303

- Magana, M.E. and Holzapfel, F. 1998. Fuzzy-logic Control of an Inverted Pendulum with Vision Feedback. *IEEE Transactions on Education*. **41**(2): 165-190
- Mallalieu, K., Ariestas, R. and So'Brien, D. 1994. An Inexpensive PC Based Laboratory Configuration for Teaching Electronics Instrumentation. *IEEE Transactions on Education*. **37**(1): 91-96
- Maskell, D.L. 1999. Student-based Assessment in a Multi-disciplinary Problem based Learning Environment. *Journal on Engineering Education*. **35**: 237-241
- Maskell, D.L. and Grabau, P.J. 1998. A Multi-disciplinary Cooperative Problem-based Learning Approach to Embedded System Design. *IEEE Transactions on Education*. **41**(3): 101-103
- Matrix Multimedia Limited. 2007. Flowcode and E-blocks for Education purposes. <http://www.matrixmultimedia.com> (16 December 2009)
- Microchip. 2005. 25LC160 Page. <http://www.microchip.com/download/en/devicedoc> (18 January 2010)
- Mitescu, S.M. 2005. *Microcontrollers in Practice*. Berlin: Springer
- Moallem, M. 2004. A Laboratory Test bed for Embedded Computer Control. *IEEE Transactions on Education*. **47**(3): 340-347
- Mohd Sapein, M.H. 2009. *Mini 11 Microcontroller Laboratory Hardware Platform with IDE Approach*. B.Eng. Thesis. Universiti Malaysia Pahang, Malaysia
- Morawski, R., Pallas Areny, R., Petriu, E. and Siegal, M. 2000. Current Trends on Teaching Instrumentation and Measurement. *16<sup>th</sup> IEEE Instrumentation Measurements Technology Conference*, pp. 1715-1726



- Mosterman, P.J. 2006. Automatic Code Generation: Facilitating New Teaching Opportunities in Engineering Education. *36<sup>th</sup> ASEE/IEEE Frontier in Education Conference*, pp. 165-171
- Mosterman, P.J., Prabhu, S. and Erkkinen, T. 2004. An Industrial Embedded Control System Design Process. *The Inaugural CDEN Design Conference*, pp. 17-21
- Motorola Inc. 2001. M68HC11E Series Family Technical Datasheet. <http://www.alldatasheet.com/motorolahc11tec.pdf> (15 September 2010)
- Muhammad Ali, M. 2000. *The 8051 Microcontroller and Embedded Systems*. Upper Saddle River, New Jersey: Prentice Hall
- Mukherjea, S. and Stasko, J.T. 1993. Applying Algorithm Animation Techniques for Program Tracing, Debugging and Understanding. *15<sup>TH</sup> International Conference on Software Engineering*. pp. 456-465
- Murray, M.R. and Garbini, J.L. 1997. Embedded Computing in the Mechanical Engineering Curriculum: A Course featuring Structured Laboratory Exercises. *Journal on Engineering Education*. **32**: 285-290
- Muttreja, A. and Raghunathan, A. 2007. Automated Energy / Performance Macro-Modeling of Embedded Software. *IEEE Transactions on Computer - Aided Design Integrations Circuits System*. **26**(3): 542–552
- Ni, J. and Luo, J. 2010. Microcontroller-based Engineering Education Innovation. *2010 International Conference on Educational and Information Technology*, pp. 109-112
- Nik Yusoff, N.M.K. 2006. DEE3263 Embedded Controller Technology. *Annual Student Performance Report*. Universiti Malaysia Pahang, Malaysia

- Nikolaidis, S., Kavvadias, N., Laopoulos, T., Bisdounis, L. and Blionas, S. 2005. Instruction Level Energy Modeling for Pipelined Processors. *Elsevier Journal on Embedded Computing*. **1**(3): 317–324
- Novak, J.D. 1990. Concept Mapping: A useful Tool for Science Education. *Journal of Research in Teaching*. **27**(10): 937-949
- Ontoria, A. 2000. *Concept Maps: A Technique for Learning*. Spain: Narcea S.A. Ed
- Palop, J.G.M. and Teruel, M.A. 2000. Virtual Work Bench for Electronic Instrumentation Teaching. *IEEE Transactions on Education*. **43** (1): 15-18
- Perez Quinones, M.A. and Cruz-Rivera, J.L. 1999. Integrated Development Environment for a Microcontroller System Laboratory. *29<sup>th</sup> ASEE / IEEE Frontiers in Education Conferences*, pp. 111-116
- Perez, M. 2003. *A Methodology of Develop Multimedia / Hypermedia Software for Education*. Ph.D. Thesis. University of North Carolina, USA
- Piguet, C., Masgonty, J.M., Arm, C. and Durand, S. 1997. Low-Power Design of 8-b Embedded CoolRisc Microcontroller Cores. *IEEE Journal of Solid-State Circuits*. **32**(7): 1067-1078
- Peatman, J.B. 1998. *Design with PIC Microcontroller*. USA: Prentice Hall
- Prasad, C.P.W., Dominic, M.M. and Singh, A.K. 2003. Variable Order Verification Use of Logic Representation. *6<sup>TH</sup> International Conference on Asian Digital Libraries*. pp. 689-695
- Predko, M. 2000. *Programming and customizing PICmicro microcontrollers*. USA: McGraw-Hill

- Qiu, M., Guo, M., Liu, M., Xue, C., Yang, L.T. and Loop, S. 2009. Scheduling and bank type assignment for heterogeneous multi-bank memory. *Journal of Parallel and Distributed Computing (JPDC)*. **69**(6): 546–558.
- Raghavan, M. 2005. *Testing of a New Wireless Embedded System*. M.Eng. Thesis. University of North Carolina, USA
- Risks, K.G. and Jackson, D.J. 2006. A Case for the VME bus Architecture in Embedded Systems Education. *IEEE Transactions on Education*. **49**(3): 332-345
- Rupp, M., Burg, A. and Beck, A. 2003. Rapid prototyping for Wireless Designs: The Five-ones Approach. *Elsevier Journal of Signal Processing*. **83**(7): 1427-1444
- Schmalzel, J.L. 1999. I&M Education for the New Millennium. *IEEE Instrumentation Measurement Magazine*. **2**(1): 31-36
- Scott, M.I. 1999. *The 8051 Microcontroller*. Upper Saddle River, New Jersey: Prentice Hall, 1999.
- Seong, K.C. 2007. *The MC68HC11 Development Board*. B.Eng. Thesis. Universiti Malaysia Pahang, Malaysia
- Sheu, S.S. and Cheng, K.H. 2011. Fast-write Resistive RAM (RRAM) for Embedded Applications. *IEEE Transaction on Design and Test of Computers*. **56**(2): 64-71
- Smith, J.E. and Nair, R. 2005. The Architecture of Virtual Machine. *IEEE Journal of Computer*. **38**(5): 32-38
- Smolnikar, M. and Mohorcic, M. 2008. A Framework for Developing a Microchip PIC Microcontroller Based Applications. *WSEAS Transactions on Advances in Engineering Education*. **5**(2): 83-91

- Spasov, P. 2004. *Microcontroller Technology - The 68HC11 and 68HC12*. USA: Pearson Education International
- Spasow, P. 1996. *Microcontroller Technology, The 68HC11*. Eaglewood Cliffs, New Jersey: Prentice Hall
- Stapleton, W.A. 2006. Microcomputer Fundamentals for Embedded Systems Education. *36<sup>th</sup> ASEE / IEEE Frontiers in Education Conference*, pp. 56-61
- Stoltz, T. 2003. *The Development of Microcontroller Hardware Platform with MC68HC11E2*. M.Eng. Thesis. University of Detroit Mercy, USA
- Stoltz, T., Paulik, M. and Al-Holou, N. 2005. A Microcontroller Laboratory Hardware Platform for Academic Environment: The UDM-EVB. *35<sup>th</sup> ASEE / IEEE Frontiers in Education Conferences*, pp. 35-40
- Striegel, A. and Rover, D. 2002. Enhanced Student Learning in an Introductory Embedded System Laboratory. *32<sup>nd</sup> ASEE / IEEE Frontiers in Education Conferences*, pp. 138-143
- Vaglica, J.J. and Gilmour, P.S. 1990. How to select a Microcontroller. *IEEE SPECTRUM*. **18**(4): 106-109
- Valdes, M.D., Moure, M.J. and Mandado, E. 1999. Educational Application of Virtual Instruments Based on Reconfigurable Logic. *IEEE MSE '99 International Conferences on Microelectronics System Education*. pp. 24-25
- Valvano, A. and Jonathan, B. 2003. *Embedded Microcomputer Systems: Motorola 6811 and 6812 Simulation*. Pacific Grove, USA: Brooks / Cole-Thomson Learning
- Vun, N. and Goh, W.B. 2007. The design of effective low cost embedded processor development kits for supporting take-home self-practice pedagogies. *2007 International Conference on Parallel and Distributed Systems*, pp. 1-7

- Watanabe, K. 1999. Instrumentation Educations in Japan: Despair and Expectation. *IEEE Instrumentation Magazines*. **2**(1): 14-19
- Wild, A., Quigley, J., Feddler, J. and Ledford, S. 1997. A 0.9V Microcontroller for Portable Applications. *IEEE Journal of Solid-State Circuit*. **32**(7): 1049-1055
- William, K. 1998. *Microprocessor and Microcontroller Fundamental*. Upper Saddle River, New Jersey: Prentice Hall
- Witte, R.A. 1999. Engineering Education for Test and Measurement Designers. *IEEE Instrumentation Measurements Magazine*. **2**(1): 11-13
- Wolf, W. and Madsen, J. 2000. Embedded Systems Education for the Future. *IEEE Transactions on Education*. **88**(1): 23-30
- Zhang, L., Qiu, M., Edwin, H.M. and Zhuge, Q. 2011. Variable assignment and instruction scheduling for processor with multi-module memory. *Elsevier Journal on Microprocessors and Microsystems*. **35**: 308-317
- Zimmermann, R. and Gupta, R. 1996. Low-Power Logic Styles: CMOS vs. CPL. 22<sup>nd</sup> *European Solid-State Circuit Conferences*. pp. 112-115
- Zotos, K., Litke, A., Chatzigeorgiou, A., Nikolaidis, S. and Stephanides, G. 2005. Energy Complexity of Software in Embedded Systems. *IASTED International Conferences in Automation and Control Applications (ACIT-ACA)*, pp. 67-71